Scattering and annihilation electromagnetic processes
ECT* Trento, 18-22 February 2013

NN physics at BESIII
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on behalf of the BESIII Collaboration

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Beijing BEPCII /BESIII

LINAC

South

BESIII detector

2004: start BEPCII construction
2008: test run of BEPCII
2009-now: BECPII/BESIII data taking
BEPCII: Beijing $e^+e^-$ double ring collider

**Design Features**
- Beam energy: $1.0 - 2.3$ GeV
- Crossing angle: 22 mrad
- Luminosity: $10^{33}$ cm$^{-2}$s$^{-1}$
- Optimum energy: 1.89 GeV
- Energy spread: $5.16 \times 10^{-4}$
- Number of bunches: 93
- Bunch length: 15 mm
- Total current: 0.91 A
- Circumference: 240 m
**BESIII Detector**

**BESIII detector:** all new!

- CsI calorimeter
- Precision tracking
- Time-of-flight + dE/dx PID

**Magnet:** 1 T  Super conducting

**Zero Degree Detector**
- new (2011)

**EMC:** CsI crystal, 28 cm
- $\Delta E/E = 2.5\%$ @ 1 GeV
- $\sigma_z = 0.6$ cm/VE

**Data Acquisition:**
- Event rate = 4 kHz
- Total data volume ~ 50 MB/s

**Muon ID:** 9 layers RPC
- 8 layers for endcap

**MDC:** small cell & Gas:
- He/C$_3$H$_8$ (60/40), 43 layers
- $\sigma_{xy} = 130$ $\mu$m
- $\sigma_{y/p} = 0.5\%$ @1GeV
- dE/dx=6%

**TOF:**
- $\sigma_T = 100$ ps  Barrel
- 110 ps  Endcap

The detector is hermetic for neutral and charged particle with excellent resolution, PID, and large coverage.
Beijing Spectrometer III (BESIII)

installation completed in April 2008
BESIII Collaboration:
http://bes3.ihep.ac.cn

EUROPE (12)
- Germany: Univ. of Bochum, Univ. of Giessen, GSI, J. Gutenberg Univ. Mainz; Helmholtz Inst. Mainz
- Russia: JINR Dubna; BINP Novosibirsk
- Italy: INFN Frascati National Lab (LNF), Univ. of Torino and Perugia
- Netherlands: KVI/Univ. of Groningen
- Sweden: Uppsala Univ.
- Turkey: Turkey Accelerator Center

Korea (1)
- Seoul Nat. Univ.

Japan (1)
- Tokyo Univ.

US (6)
- Univ. of Hawaii
- Univ. of Washington
- Carnegie Mellon Univ.
- Univ. of Minnesota
- Univ. of Rochester
- Univ. of Indiana

Pakistan (2)
- Univ. of Punjab
- Comsats IIT

China (29)
- IHEP, CCAST, Shandong Univ., Univ. of Sci. and Tech. of China
- Zhejiang Univ., Huangshan Coll.
- Huazhong Normal Univ., Wuhan Univ.
- Zhengzhou Univ., Henan Normal Univ.
- Peking Univ., Tsinghua Univ., Zhongshan Univ., Nankai Univ.
- Shanxi Univ., Sichuan Univ.
- Hunan Univ., Liaoning Univ.
- Nanjing Univ., Nanjing Normal Univ.
- Guangxi Normal Univ., Guangxi Univ.
- Suzhou Univ., Hangzhou Normal Univ.
- Lanzhou Univ., Henan Sci. and Tech. Univ.
- Hong Kong Univ., Hong Kong Chinese Univ.

Univ. of South China, UCAS.

52 institutes from 11 countries
> 300 collaborators
Physics in the tau-charm region

- **Light hadron physics**
  - Spectroscopy: normal and exotic hadrons QCD
  - How quarks form hadron? non-pQCD
  - Baryon e.m. form factors

- **Charm physics**
  - Full spectra CKM matrix elements $\rightarrow$ SM and beyond
  - $D\bar{D}$ mixing and CPV $\rightarrow$ SM and beyond

- **Charmonium physics**
  - Spectroscopy and transition $\rightarrow$ pQCD & non-pQCD
  - New states above open charm thresholds $\rightarrow$ exotic hadrons?
  - pQCD: $\rho\pi$ puzzle $\rightarrow$ a probe to non-pQCD or?

- **Tau physics and QCD**
  - Precision measurement of the tau mass and $R$ measurement

- **Search for rare and forbidden decays**
  
  Precision tests of SM and search for new physics

arXiv: 0809.1869
**BESIII timeline**

- **July 19, 2008:** first $e^+e^-$ collision event in BESIII
- **Nov 2008:** $\sim$14M $\psi(2S)$ events for detector calibration

**2009:**
- 106M $\psi(2S)$ 4xCLEOc
- 225M $J/\psi$ 4xBESII

**2010-11:**
- 2.9 fb$^{-1} \psi(3770)$ 3.5xCLEOc

**2011:**
- 0.5 fb$^{-1}$ @4.01GeV ($D_s$, XYZ)

**2012:**
- 0.4B $\psi(2S)$
  - $J/\psi$: 1B events, lineshape fine scan,
  - scan for $J/\psi$ phase measurement, 14pb$^{-1}$/point, tot 5 points
  - R scan @ 2.23, 2.4, 2.8, 3.4 GeV

**2013:**
- 515 pb$^{-1}$ @ 4260 MeV
- 40 pb$^{-1}$ @ 4190, 4210, 4230 MeV

- **Peak luminosity:** $6.5 \times 10^{32}$ cm$^{-2}$s$^{-1}$ @ 3770MeV

**the world's largest set of $J/\psi$ $\psi(2S)$ $\psi(3770)$ and still growing!**
BESIII plans

• Current run: December 2012 – June 2013
  
  >500 pb\(^{-1}\) @ 4360 MeV  *almost done*
  5 days Y(4360) scan
  60 days R scan: \(\sim 100\) pts > 3.8 GeV, 5-8 pb\(^{-1}\)/pt, 2-3% precision
  10 days \(\tau\) scan
  additional \(\psi(3770)\)

• foreseen luminosity: \(\rightarrow 10^{33}\) cm\(^{-2}\)s\(^{-1}\) @ 3770 MeV
Published BESIII results

$\chi_{cJ}$ decays and transitions

1) Search for hadronic transition $\chi_{cJ} \rightarrow \eta, \pi^\pm \pi^\mp$ and observation of $\chi_{cJ} \rightarrow \Lambda \bar{\Lambda} \pi^\pm \pi^\mp$. PRD87, 012002 (2013)
2) Measurement of $\chi_{cJ}$ decaying into $p \pi^0$ and $\bar{p} \pi^0$. PRD86, 052011 (2012)
3) Observation of $\chi_{cJ}$ Decays to $\Lambda \bar{\Lambda} \pi^\pm \pi^\mp$. PRD86, 052004 (2012)
4) Two-photon widths of the $\chi_{cJ}$ states and helicity analysis for $\chi_{cJ} \rightarrow \gamma \gamma$. PRD85, 112008 (2012)
5) Observation of $\chi_{cJ}$ decays into vector meson pairs $\omega \omega$, $\omega \omega$, and $\omega \omega$. PRL107, 092001 (2011)
6) Study of $\chi_{cJ}$ radiative decays into a vector meson. PRD83, 112005 (2011)
7) First Observation of the Decays $\chi_{cJ} \rightarrow \pi^0 \pi^0 \pi^0 \pi^0$. PRD83, 012006 (2011)

Studies of $\eta$, $\eta$, $\eta(1405)$, $\eta_c$ and $\eta'_c$ mesons

8) Observation of $\eta(2S)$ in $\psi^\prime \rightarrow \eta \chi, K^\pm \pi^\mp$. [arXiv:1301.1476]
9) Search for weak decays of $\eta$ and $\eta'$ in $J/\psi \rightarrow \phi \eta(\eta')$. [arXiv:1211.3600]
10) Measurements of Baryon pair decays of $\chi_{cJ}$ mesons. [arXiv:1211.2283] accepted by PRD
11) Observation of $\eta_c$ decaying into $\Sigma^+ \Sigma^-$ and $\Xi \Xi'$. PRD87, 012003 (2013)
12) The analysis on $h_c$ exclusive decays into $\gamma \eta_c$. PRD86, 092009 (2012)
13) Search for $\eta$ and $\eta'$ Invisible Decays in $J/\psi \rightarrow \eta \eta$ and $\eta \eta'$. [arXiv:1209.2469]
14) Observation of $e^+ e^- \rightarrow \eta / \eta '$ at center-of-mass energy $s^{1/2} = 4.09$ GeV. PRD86, 071101 (2012)
15) Evidence for $\eta \rightarrow \gamma \gamma$ and Measurement of $J/\psi \rightarrow 3 \gamma$. [arXiv:1208.1461]
16) First observation of $\eta(1405)$ decays into $f_0(980) \eta^0$. PRL108, 182001 (2012)
17) Measurements of the mass and width of the $\eta_c$ using $\psi^\prime \rightarrow \gamma \eta_c$. PRL108, 222002 (2012)
18) Search for $\eta_c$ decays into vector meson pairs. PRD84, 091102 (2011)
19) $\eta \pi^+ \pi^-$ Resonant Structure around 1.8 GeV/$c^2$ and $\eta(1405)$ in $J/\psi \rightarrow \omega \eta \pi^+ \pi^-$. PRL107, 182001 (2011)
20) Search for CP and P violating pseudoscalar decays into $\pi \pi$. PRD84, 032006 (2011)
21) Measurement of the Matrix Element for the Decay $\eta^\prime \rightarrow \eta \pi^+ \pi^-$. PRD83, 012003 (2011)
Published BESIII results

Decays of $c\bar{c}$ mesons

22) Partial wave analysis of $J/\psi \to \gamma \eta\bar{\eta}$. [arXiv:1301.0053]
23) PWA of $J/\psi \to \phi \omega$. [arXiv:1211.5668] accepted by PRD
24) Measurements of $\psi' \to \Lambda K^0$ and $\Lambda K$ [arXiv:1211.563] accepted by PRD
25) Measurement of $\psi' \to \gamma \phi K\Lambda$. [arXiv:1211.5633] accepted by PRD
26) Measurement of branching fractions for $J/\psi$ an $\psi(3686)$ to $\Lambda \Lambda \pi^0$ and $\Lambda \Lambda \eta$. [arXiv:1211.4682]
27) Precision measurement of branching fractions of $\psi' \to \pi^0 J/\psi$ and $\eta J/\psi$. PRD86, 092008 (2012)
28) Determination of the number of $\psi(2S)$ events at BESIII. [arXiv:1209.6199]
29) Experimental study of $\psi'$ decays to $K^+ K^- \pi^0$ and $K^+ K^- \eta$. PRD86, 072011 (2012)
30) First observation of the isospin violating decay $J/\psi \to \Lambda \Lambda \gamma^{\pm}$ c.c.. PRD86, 032008 (2012)
31) Determination of the number of $J/\psi$ events with $J/\psi \to$ inclusive decays. [arXiv:1207.2865]
32) Observation of two new $N^*$ resonances in $\psi(3686) \to p\bar{p} \pi^0$. [arXiv:1207.0223]
33) First observation of the M1 transition $\psi(3686) \to \gamma \gamma \eta \gamma$. (2S). PRL109, 042003 (2012)
34) Study of $J/\psi \to \gamma \eta$ and $J/\psi \to \pi^0$. PRD86 (5), 032014 (2012)
35) Evidence for the Direct Two-Photon Transition from $\psi'$ to $J/\psi$. [arXiv:1204.0246]
36) Precision measurement of the branching fractions of $J/\psi \to \pi^+ \pi^- \pi^0$ and $\psi' \to \pi^+ \pi^- \pi^0$. PLB710, 594 (2012)
37) Spin-Parity Analysis of $p\bar{p}$ Mass Threshold Structure in $J/\psi$ and $\psi'$. Radiative Decays. PRL108 112003 (2012)
38) Higher-order multipole amplitude measurement in $\psi(2S) \to \gamma \eta \eta$. PRD84, 092006 (2011)
39) Evidence for $\psi'$ decays into $\gamma \eta$ and $\gamma \eta$. PRL105 261801 (2010)

Scalar mesons and new states

39) Search for a light Higgs-like boson $A_0$ in $J/\psi$ radiative decays. PRD85 092012 (2012)
40) Study of $a_0(980)$--$f_0(980)$ mixing. PRD83, 032003 (2011)
41) Confirmation of the $X(1835)$ and observation of the resonances $X(2120)$ and $X(2370)$ in $J/\psi \to \gamma \pi^+ \pi^- \eta'$. PRL106, 072002 (2011)
Baryonium (?) and new structures at BESIII
Anomalous $M_{pp\bar{p}}$ threshold enhancement @ BESII

$J / \psi \rightarrow \gamma p\bar{p}$

**Theoretical interpretation:**
- conventional meson?
- ppbar bound state/multiquark/Baryonium?
- glueball
- Final state interaction (FSI)
- ...

$M = 1859^{+3}_{-10}^{+5}_{-25}$ MeV/c$^2$

$\Gamma < 30$ MeV/c$^2$ (90% CL)

PRL 91 (2003) 022001
Confirmation @ BESIII and CLEOc

Fit with one resonance at BESIII:

\[ \psi' \rightarrow \pi^+\pi^- J/\psi, J/\psi \rightarrow \gamma p\bar{p} \]

**BESIII**

\[ M = 1861^{+6}_{-13}^{+7}_{-26} \text{ MeV/c}^2 \]

**CLEOc**

\[ \Gamma < 38 \text{ MeV/c}^2 \text{ (90\% CL)} \]

Chinese Physics C 34, 421 (2010)

PRD 82, 092002(2010)
Several non-observations

$Y(1S) \rightarrow \gamma pp \ @CLEO$

$J/\psi \rightarrow \omega pp \ @BESII$

$\psi' \rightarrow \gamma pp \ @BESII$

$\psi(2S) \rightarrow \gamma pp \ @CLEOc$

Pure FSI interpretation is disfavored
PWA of $J/\psi \rightarrow \gamma p\bar{p}$ @ BESIII

- PWA of $J/\psi \rightarrow \gamma p\bar{p}$

- The fit with a BW and S-wave FSI(I=0) factor can well describe ppb mass threshold structure.
- It is much better than that without FSI effect
- Different FSI models $\rightarrow$ Model dependent sys. uncertainty

- $X(p\bar{p})$ Spin-parity, mass, width and B.R.:
  
  $J^{PC} = 0^{++}$  
  $M = 1832^{+19}_{-25} \text{ (stat)}^{+16}_{-17} \text{ (syst)} \pm 19 \text{ (mod) MeV}/c^2$
  $\Gamma = 13 \pm 20 \text{ (stat)}^{+11}_{-15} \text{ (syst)} \pm 4 \text{ (mod) MeV}/c^2$ or $\Gamma < 76 \text{ MeV}/c^2 \text{ @ 90\% C.L.}$
  $B(J/\psi \rightarrow \gamma X(p\bar{p}))B(X(p\bar{p}) \rightarrow p\bar{p}) = (9.0^{+0.4}_{-1.1} \text{ (stat)}^{+1.5}_{-0.3} \text{ (syst)} \pm 2.3 \text{ (mod)}) \times 10^{-5}$
M_{pp\overline{p}} threshold structure of $\psi' \rightarrow \gamma p\overline{p}$ @ BESIII

Obviously different line shape of ppbar mass spectrum near threshold from that in $J/\psi$ decays

**PWA results:**
- Significance of $X(pp\overline{p})$ is $> 6.9\sigma$.
- The production ratio $R$:
  \[ R = \frac{B(\psi' \rightarrow \gamma X(p\overline{p}))}{B(J/\psi \rightarrow \gamma X(p\overline{p}))} \]
  \[ = (5.08^{+0.71}_{-0.45} \text{ (stat)})^{+0.67}_{-3.58} \text{ (syst)} \pm 0.12 \text{ (mod)} \]%
- It is suppressed compared with “12% rule”.

**PWA Projection:**

*first measurement*

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PRL 108, 112003(2012)
Confirmation of X(1835), and new observation of X(2120), X(2370) in J/ψ → γη π⁺π⁻

- BESII result [PRL95, 262001 (2005)] observation of X(1835) with significance: ~7.7σ

- BESIII [PRL 106, 072002 (2011)] confirmation:
  - M = 1836.5±3.0(stat) +5.6 −2.1(sys) MeV/c²
  - Γ = 190.0±9.0(stat) +38.3 −36(syst) MeV/c²
  - Significance: >20σ

- Two additional new resonances, X(2120) and X(2370), are observed with significance larger than 7.2σ and 6.4σ, respectively.

- X(p̅p) and X(1835) are consistent to be the same state but different widths

Further studies foreseen.
$J/\psi$ strong and electromagnetic phase
\( \psi' \) Strong and Electromagnetic Decay Amplitudes

**Resonant contributions**
\[
\Gamma_{\psi'} \sim 93\text{KeV} \rightarrow pQCD
\]
pQCD: all amplitudes almost real \(^{[1,2]}\)
\[
QCD \rightarrow \Phi_p \sim 10^\circ \] \(^{[1]}\)

**Non-resonant continuum**
\[
pQCD \text{ regime}
A_{EM} \in \mathbb{N}
\]

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$J/\psi$ Strong and Electromagnetic Decay Amplitudes

- If both real, they must interfere ($\Phi_p \sim 0^\circ/180^\circ$)
- On the contrary $\Phi_p \sim 90^\circ \rightarrow$ No interference
- $J/\psi \rightarrow NN (\frac{1}{2}^+ \frac{1}{2}^-) \quad \Phi_p = 89^\circ \pm 15^\circ$\(^\text{[1]}\); $89^\circ \pm 9^\circ$\(^\text{[2]}\)
- $J/\psi \rightarrow VP (1\cdot0^-) \quad \Phi_p = 106^\circ \pm 10^\circ$\(^\text{[3]}\)
- $J/\psi \rightarrow PP (0\cdot0^-) \quad \Phi_p = 89.6^\circ \pm 9.9^\circ$\(^\text{[4]}\)
- $J/\psi \rightarrow VV (1\cdot1^-) \quad \Phi_p = 138^\circ \pm 37^\circ$\(^\text{[4]}\)

- Results are model dependent

- Model independent test:
  
  interference with the non resonant continuum

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\[ J/\psi \rightarrow p\bar{p}, n\bar{n} \]

- The \( J/\psi \rightarrow N\bar{N} \) is a very good test of pQCD
- The 3 gluons in the OZI-violating strong amplitude just match the 3 q\bar{q} pairs of NN final states
- dominant strong amplitude: \( |A_{3g}^N| > |A_{3g}^N| \)
- isospin symmetry \( \rightarrow |A_{3g}^p| = |A_{3g}^\gamma| \)
- \( A_p^p \) and \( A_p^\gamma \) have opposite sign just as magnetic moments
- assuming pQCD: strong and e.m. amplitudes are Real \( \rightarrow \) maximum interference and:

\[ R = \frac{BR(J/\psi \rightarrow p\bar{p})}{BR(J/\psi \rightarrow n\bar{n})} = \left| \frac{A_{3g}^p + A_{3g}^\gamma}{A_{3g}^p + A_{3g}^\gamma} \right|^2 = 2 \]
Recent BESIII results:
\[ BR(\psi \rightarrow p\bar{p}) = (2.112 \pm 0.004 \pm 0.027) \times 10^{-3} \]
\[ BR(\psi \rightarrow n\bar{n}) = (2.07 \pm 0.01 \pm 0.14) \times 10^{-3} \]

Published: PRD86 (5), 032014 (2012)

PDG:
\[ BR(\psi \rightarrow p\bar{p}) = (2.17 \pm 0.07) \times 10^{-3} \]
\[ BR(\psi \rightarrow n\bar{n}) = (2.2 \pm 0.4) \times 10^{-3} \]

\[ BR(\psi \rightarrow p\bar{p}) \sim BR(\psi \rightarrow n\bar{n}) : \]
\[ A_{3g}^N \perp A_{\gamma}^N \]
Large relative phase \( 89^\circ \pm 9^\circ \)!
A model independent way to measure the phase between strong and e.m. decay amplitudes

- So far experimentally: $\Phi_p \sim 90^\circ \rightarrow$ Imaginary strong amplitudes hard to explain but results are model dependent

- Model independent test: look for interference pattern between the resonant amplitude and the non resonant continuum through a c.m. energy scan, i.e. out of $J/\psi$ peak

- **No interference**: $\Phi_p \sim 90^\circ$, (Imaginary strong amplitude!)
- **Maximum interference**: $\Phi_p \sim 0^\circ, 180^\circ$ (Real strong amplitude)
Simulated Yields for $e^+e^- \to p\bar{p}$

- $\Delta\varphi = 0^\circ$
- $\Delta\varphi = 90^\circ$
- $\Delta\varphi = 180^\circ$

continuum reference
$\sigma \sim 11$ pb

no corrections

beam energy spread
(0.93 MeV)

beam energy spread + radiative corrections
No $A_{3g}$ in $e^+e^- \rightarrow \mu^+\mu^-$ due to leptonic decay. No $A_{3g}$ in $e^+e^- \rightarrow 2(\pi^+\pi^-)$ due to G-parity. Only $A_\gamma$ and $A_{cont.}$ contributions.

\[ \sigma_{tot} \sim |A_\gamma + A_{cont.}| = |A_\gamma|^2 + |A_{cont.}|^2 + 2 \text{Re}[A_\gamma^* A_{cont.}] . \]

$A_{cont.}$ has the same phase as $A_\gamma \rightarrow \phi \sim 0^\circ$ expected.
Interference observed in $e^+e^- \rightarrow J/\psi \rightarrow \mu^+\mu^-$?

Interference pattern between $J/\psi$ decay and the non-resonant decay amplitudes first observed at SLAC [PRL 33,1406] in 1975. Confirmed by BESII and KEDR,

BESIII analysis in progress...
Interference in $e^+e^- \rightarrow \pi^0\pi^+\pi^-\pi^+\pi^-(\pi^+\pi^-\pi^0)$

G-parity conserves. $A_{3g}$ contributes.

$\sigma_{tot} \sim |A_{strong} + A_{EM}|^2 = |A_{strong}|^2 + |A_{EM}|^2 + 2Re[A_{strong}^*A_{EM}]$

$A_{EM}$ includes $A_\gamma$ and $A_{cont.}$

What about $e^+e^- \rightarrow \pi^02(\pi^+\pi^-)$ around $J/\psi$?

BESIII analysis in progress...
Investigated processes in BESIII

- **Exclusive scenario: no interference?**
  
  - \( e^+e^- \rightarrow J/\psi \rightarrow p\bar{p}, n\bar{n}, N\bar{N} \) \( \text{BR} \sim 2.17 \times 10^{-3} \) \( \sigma_{\text{cont}} \sim 11 \text{ pb} \)
  
  - \( e^+e^- \rightarrow J/\psi \rightarrow \rho\pi \) \( \text{VP} \) \( \text{BR} \sim 1.69\% \) \( \sigma_{\text{cont}} \sim 20 \text{ pb} \)
  
  - \( e^+e^- \rightarrow J/\psi \rightarrow 2(\pi^+\pi^-)\pi^0 \) \( \text{BR} \sim 5.5\% \) \( \sigma_{\text{cont}} \sim 500 \text{ pb} \)

- **Check processes where expected interference:**
  
  - \( \mu^+\mu^- \): full interference expected \( (A_{3g}=0) \)
  
  - even number of \( \pi \): no strong contribution due to \( G \) parity

- **BESIII analysis in progress**

- **STAY TUNED!**
Initial State Radiation: Physics Motivations

- Existing results, mainly from BABAR (ISR) show interesting and unexpected behaviors especially at threshold for $e^+e^- \rightarrow p\bar{p}$, $e^+e^- \rightarrow \Lambda\bar{\Lambda}$
- Scarse measurement (energy scan) for $e^+e^- \rightarrow n\bar{n}$

Physical limits in reaching threshold of many of these channels via energy scan (stable hadrons produced at rest cannot be detected)

The ISR technique provides a unique tool to access threshold regions working at higher resonances
Initial State Radiation

Advantages
- all energies ($q^2$) at the same time → better control on systematics
- detect ISR photon → full $X_{had}$ angular coverage
- CM boost → at threshold $E#0$, energy resolution~1 MeV
ISR: BESIII vs BABAR for $\sigma (p\bar{p})$

\[
\frac{d^2L}{d\cos\theta_\gamma d\sqrt{s}} = \frac{2\sqrt{s} L_{e^+e^-}}{E_{CM}^2} \frac{\alpha}{\pi x} \left( \frac{2-2x+x^2}{\sin^2\theta_\gamma} \right) \left( \frac{x^2}{2} \right)
\]

$L_{e^+e^-}$ = luminosity

\[
x = \frac{2E_\gamma}{E_{CM}} = 1 - \frac{s}{E_{CM}^2}
\]

- $E_{CM}^{BABAR} = 10.58$ GeV
- $E_{CM}^{BESIII} = 3.69$ GeV
- $\theta_\gamma \in [20^\circ, 160^\circ]$
ISR: angular distribution and zero degree photon tagging

\[ \frac{dN}{d \cos \theta_{\gamma}} = \frac{1 - \cos \theta_{\gamma}^2}{\left(1 - \beta_{\gamma}^2 \cos^2 \theta_{\gamma}\right)^2} \]

\[ \beta_{\gamma} = \sqrt{1 - \frac{4m_\gamma^2}{E_{\text{CM}}^2}} \]

With a typical \( \theta_{\gamma}^{\text{min}} = 20^\circ \)
\( \sim 80\% \) of events is lost!

With \( \theta_{\gamma}^{\text{max}} = 3 \text{ mrad} \), more statistics than at wide angle!
BESIII zero degree detector

- $J/\psi$, $\psi(2S)$, $\psi(3770)$ resonances decay with high BR's to final states with $\pi^0$ and $\gamma_{FS}$ (final state)
- At BESIII these decay channels represent severe backgrounds for typical ISR final states with $\gamma_{IS}$ detected at wide angle

- $\pi^0$ and final $\gamma$ angular distributions are isotropic
- ISR angular distribution is peaked at small angles

A zero-degree radiative photon tagger will suppress most of these backgrounds

A new zero-degree detector (ZDD), has been installed on summer 2011 at BESIII to tag ISR photons as well as to measure the luminosity
ZDD: structure module and segmentation

Pb/Sci.Fi Array a la KLOE scintillating material 60% of total (in volume) two modules (up and down the beam) dimensions: 14×4×6 cm³
signal extracted and channeled to PM through bundles of clear optical fibers (2m long)

Each sector is sent to a PM, sectors 1 & 2 (6 & 7) are sent to the same PM
ZDD as luminometer

ZDD rate for 72 bunches
Prospects for baryon form factors
\( e^+ e^- \rightarrow p\bar{p} \)  

\[
\sigma(e^+ e^- \rightarrow p\bar{p}) = \frac{4\pi \alpha^2 \beta_p C}{3q^2} \left| G_m \right|^2 + \frac{2M_p^2}{q^2} \left| G_E \right|^2
\]

Coulomb factor:
\[
C \sim \left( \frac{\pi\alpha}{\beta_p} \right)
\]

At threshold:
\[
\sigma(e^+ e^- \rightarrow p\bar{p})(4M_p^2) = \frac{\pi \alpha^3 \beta_p}{2M_p^2} G_p(4M_p^2)^2 \text{ nb}
\]
\[
\sigma(e^+ e^- \rightarrow p\bar{p})(4M_p^2) = 850 \left| G_p(4M_p^2)^2 \right| \text{ pb}
\]

\(|G_p(4M_p^2)| = 1\) as pointlike fermion pairs!

Using ISR technique with only few fb\(^{-1}\) of integrated luminosity BESIII can easily achieve the BABAR statistics
$e^+ e^- \rightarrow n\bar{n}$


$|G^n(q^2)|$

- FENICE
- DM2
- $\Delta$ DM2 extr. from $G^\Lambda$
- $|G^p : Q_d/Q_u|$

| $|G^p/G^n|$ |
|------------------|
| Data             | $\sim 1.5$ |
| Naively          | $\sim |Q_d/Q_u|$ |
| pQCD             | $< 1$      |
| Soliton models   | $\sim 1$   |
| VMD (Dubnicka)   | $\gg 1$    |

only SND, CMD2(?) and BESIII have the possibility to measure this cross section
$e^+e^- \rightarrow n\bar{n}$

- measured by FENICE at ADONE
  
- recently confirmed by SND
  
- $\sigma(n\bar{n}) > \sigma(p\bar{p})$?
  
- Not zero at threshold?
Expectations for $n\bar{n}$, $p\bar{p}$ at BESIII

- One year of data taking: $T = 1.5 \times 10^7$ s
- Average luminosity: $\overline{\mathcal{L}} = 3 \times 10^{32}$ cm$^{-2}$s$^{-1}$
- Center of mass energy: $E_{\text{c.m.}} = 3.77$ GeV
- Detection efficiencies:
  - $\epsilon_{n\bar{n}} = 0.4$
  - $\epsilon_{p\bar{p}} = 0.8$
- Number of events:
  - $N_{n\bar{n}} \simeq 1000$
  - $N_{p\bar{p}} \simeq 2000$

Graph showing $\sigma_{n\bar{n}}$ (mb) vs. $\sqrt{q^2}$ (GeV) for BES III and FENICE.
Conclusions

- BESIII is running successfully
- Many interesting physics analyses going on and new ones to start
- More precise data on $\sigma_{pp}$ above 3GeV
- Unique possibility to measure the $n\bar{n}$ cross section with ISR and scan
- Measurement of the relative phase between e.m. and strong amplitudes in $J/\psi$, $\psi'$ decays
- First BESIII result confirms a large phase scenario and considerably improve PDG data on $J/\psi \to NN$